ABRADED RIPPLE-MARKED SURFACES IN COLUMBUS LIMESTONE, CENTRAL OHIO[1]

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ABSTRACT

Quarrying in Scioto Township, Delaware County, Ohio, in 1966–67 uncovered an area of well-developed ripple marks at the top of the Columbus Limestone (Middle Devonian) and beneath a few inches of "bone bed" at the base of the overlying Delaware Limestone. The ripples averaged about 19 inches in wavelength and 1.5 inches in ripple height; they had smoothly rounded crests and were notably symmetrical. Their trend was N23°W. The ripple-marked surface beveled corals and other fossils, and merged laterally into a type of surface long known locally as "smooth rock," which is clearly a surface of abrasion. In all these respects the rippled surface is remarkably similar to others in the Columbus Limestone, reported many years ago, that are as much as 85 miles away.

A two-stage history of formation is indicated. First, waves produced ripple marks in poorly sorted carbonate sands on a shallow bottom. Later, after consolidation of the sediment, storm waves were agents of intense scouring and smoothing of the bottom. The later part of this history seems to be confirmed by analogy with a carbonate deposit of Holocene age.

INTRODUCTION

Well-developed ripple marks at the top of the Columbus Limestone, which were progressively exposed and destroyed in 1966–67 at a quarry in central Ohio, were observed and described on several visits. Interpretation of their origin and significance leads to a consideration of other occurrences in the Columbus Limestone, and to a comparison with an occurrence of modern carbonates.

The quarry where the ripple marks were observed is operated by the National Lime and Stone Company and is situated in Scioto Township, Delaware County, Ohio. It is 18 miles northwest of Columbus and four miles southwest of Delaware, at a locality known as Klondike. Here approximately 20 feet of till of Wisconsin age is underlain by 15 feet of Delaware Limestone, and this in turn by Columbus Limestone, of which about 30 feet is quarried (fig. 1). Both limestone formations carry abundant marine fossils of Middle Devonian age. The Delaware is a medium-gray slabby limestone that is used for crushed stone; the Columbus is a light-gray "high-calcium" stone, which is utilized in a lime-manufacturing plant adjacent to the quarry.

At the base of the Delaware Limestone at this locality is a unit of limestone four to eight inches thick that contains many small dark fragments of the bones and teeth of fishes. This "bone bed" is one of several thin, distinctive units that occur in the Delaware Limestone and in the underlying Columbus and its correlatives. The one at Klondike is the "Second Bone Bed" of Wells (1947). Though Wells placed this bed at the top of the Columbus, Conkin (1969) follows Westgate and Fischer (1933) in placing it in the Delaware on both faunal and physical grounds. In the quarry at Klondike, a bench is developed at the position of the bone bed.

RIPPLE-MARKED SURFACE

The ripple-marked surface seen at the Klondike quarry occurred directly beneath the bone bed, that is, at the top of the Columbus Limestone. When first visited by the writer in July, 1966, the surface was exposed in a corner of the quarry, where it extended the full width of the bench (fig. 2). More of the rippled surface was uncovered as quarrying proceeded eastward, but by mid-1968 the

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ripples had disappeared in that direction. Quarrymen report that they encountered no ripples on the surface as earlier exposed to the north and south. A reasonable conclusion is that the rippled area was of local extent, occupying perhaps two or three acres.

Trend of the ripples was N23°W. They were symmetrical and had rounded

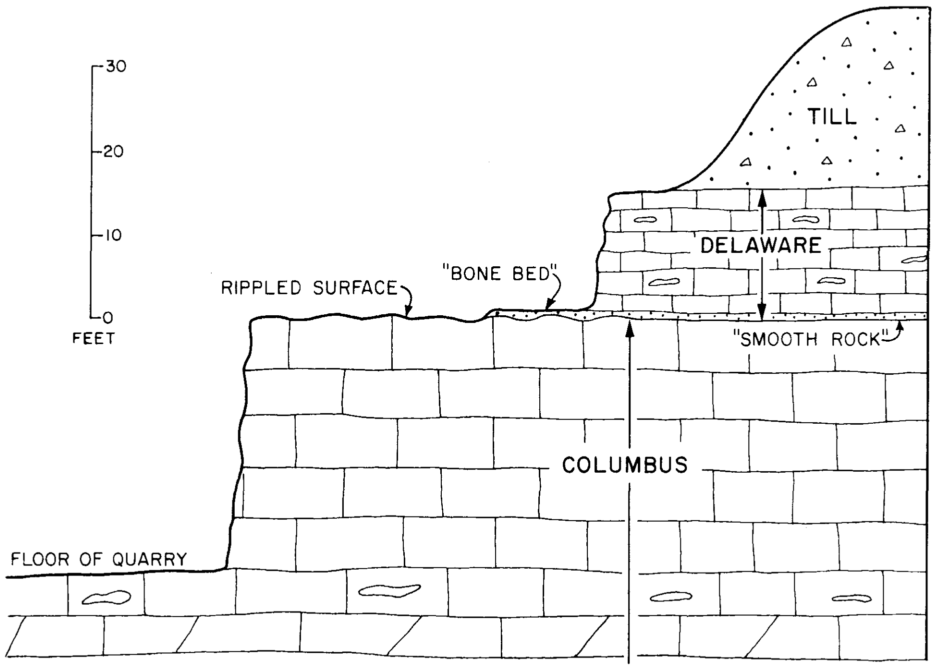

FIGURE 1. Section at Klondike quarry of National Lime and Stone Company, Delaware County, Ohio.

crests (fig. 3). Wavelength ranged from 18 to 24 inches, averaging about 19 inches; ripple height was 0.9 to 1.8 inches, with an average of about 1.5 inches. Ripple index was approximately 13. Individual ripples were persistent for many feet. In places they subdivided, elsewhere combined with their neighbors.

The rippled surface was very smooth, and beveled corals and other fossils. It was clearly a surface of abrasion. Implications of this fact are discussed in later paragraphs.

ROCK FABRIC

A factor that bears on the origin of rippled surfaces is the nature of the underlying material, especially its fabric. Two thin sections and two sets of sawed and etched sections of the Columbus Limestone immediately below the rippled surface were made and examined.

One thin section was made parallel to the ripple trend and the other transverse. Study of these sections shows the rock to be a silty, poorly sorted calcarenite, with no discernible evidence of preferred orientation of clasts. Because thin sections are small in comparison with the size of the ripples, two slabs of the rippled limestone were sawed and etched for study. One slab came from the trough between ripples, and the other from the crest of a ripple. Each was sawed in three directions: parallel to the trend, transverse to the trend, and at right angles to both of these directions, or approximately horizontally. Dimensions of the

FIGURE 2. Ripple-marked surface exposed in 1966 at the Klondike quarry. Rock fragment at right is about 2.5 feet in diameter.

cut surfaces average about three by five inches; one edge of each vertical section is made by the ripple-marked surface. Each section was etched lightly in dilute hydrochloric acid and then examined under a binocular microscope.

Examination of the three sections of the sample taken from the trough shows the rock to be a poorly sorted fossil-hash calcarenite with an appreciable fraction of calcareous silt. The normal sediment is interrupted by irregular burrows, by air bubbles, and by fossil cavities that contain rounded sand-size grains in the lower part and clear calcite above. Fragments of fish bones and teeth from the

FIGURE 3. Rippled surface disappearing beneath bone bed (behind hammer). Klondike quarry.

overlying bone bed, some of them pyritized, may be seen in the larger burrows. Invertebrate fossils, mostly fragmental, include corals, brachiopods, gastropods, crinoids, and trilobites. The normal calcarenite is close to light olive-gray (5Y6/1), whereas the burrows tend to be darker, in the range of medium gray (N5). Irregular dolomitized patches are dark yellowish-brown (10YR4/2). The horizontal section reveals rock that is notably mottled, as it cuts through burrows, dolomitized areas, and undisturbed calcarenite.

The three sections from the ripple crest show somewhat better sorting than in the trough, with less silt and no large fossil fragments. Many sand-sized bits of fish bones and teeth are plastered on the ripple surface, and some have sifted down into the larger burrows.

In neither set of sections is there evidence of cross-lamination or other preferred orientation or directional fabric. Stratification, where it can be detected at all, is faintly horizontal.

The bone bed was also sectioned and examined. The limestone of this unit is very poorly sorted, grain sizes ranging from that of silt to fossil fragments more than an inch long. The coarsest shell fragments occur in the bottom 1.5 inches, just above the ripple-marked surface. Perhaps 10 to 15 percent of the sand-sized grains are fragments of collophanized fish bones and teeth; some of the bone fragments are larger than sand size. Bedding is crudely horizontal. Shell fragments are oriented at all angles, several being convex upward. Large shells are partly silicified. The cement is clear crystalline calcite. Color of the limestone is light olive-gray (5Y6/1), speckled with the dark brown of the bone fragments.

OTHER OCCURRENCES

Ripples of the type described here have been known for many years from exposures of the Columbus Limestone at the Marble Cliff quarries in Columbus (Hubbard *et al.*, 1915, p. 38–46). According to Westgate and Fischer (1933), rippled surfaces occur at at least three levels within 30 feet of the top of the Columbus in central Ohio. At an abandoned quarry at Owens, 40 miles north of Columbus and five miles south of Marion, ripples with dimensions and orientations much like those at Klondike are still exposed (fig. 4). A typical Owens ripple has a wavelength of 25.5 inches and a height of 1.0 inch. The trend is N22°W.

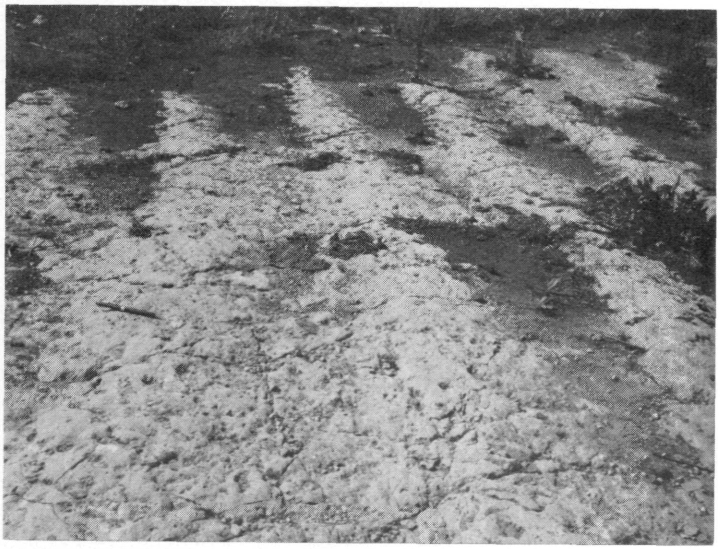

FIGURE 4. Ripple-marked surface at Owens quarry, south of Marion, Ohio. Pencil at left points to a truncated solitary coral.

In a paper that has become something of a classic, Prosser (1916) described nine examples of ripple marks in Ohio limestones. Eight of these, in Ordovician and Silurian rocks, are mostly asymmetrical and of relatively large ripple height. The one Devonian example, however, is remarkedly similar to those at Klondike and Owens, as is shown not only by Prosser's description but by his photographs. These ripples were found in the "upper part of the Columbus limestone." Their wavelength averaged about 24 inches; ripple height was not determined but the ripples were "rather shallow." No lack of symmetry could be detected. As at Klondike and Owens, the trend was N20–25°W. All this is of exceptional interest because these ripples were in a quarry at Sandusky, 85 miles north of the ones at Klondike and more than 100 miles from those at Columbus.

ORIGIN OF THE RIPPLES

The general form and appearance of the ripples suggest that they are oscillation features, formed by wave action. They show four characteristics of wave ripples as set forth by Harms (1969). These are symmetry, rounded profiles, slopes at less than the angle of repose, and continuous well-oriented crests. The underlying rock shows no evidence of cross-lamination by currents.

The paleogeographic position of the rippled strata also seems to suggest the action of waves rather than of currents. All evidence suggests that the Columbus Limestone accumulated on a broad carbonate shelf. Remoteness from land, or at least negligible influence by land, is shown by the very low noncarbonate content of the rock; the upper part of the Columbus is utilized for high-purity stone for more than 100 miles along its strike, and as far down the dip as Barberton, some 70 miles east of the present outcrop. The abundance of corals and other marine forms suggests that the sea was warm, clear, and agitated. A shallow-water carbonate platform, thousands of square miles in extent, is indicated.

As pointed out by Oliver and others (1967), limestones of Onondaga age (Columbus and equivalents) probably extended in a continuous sheet from Ohio into Michigan, Ontario, and Indiana. Though the limestone sheet pinches out in southern Ohio, a remnant is present further to the south, in east-central Kentucky, and there is limestone of Onondaga age in western Kentucky. Oliver and others state that the limestone sheet extended farther onto the Cincinnati Arch than did older units, and at times may even have blanketed it.

Wells (1944, 1947), largely following Romer and Grove (1935), concludes that the fish remains found in the bone beds, and also those of the Ohio Shale (Upper Devonian), were derived from fishes of freshwater habitat. These came from the lowland of Cincinnatia, and on dying were washed out to sea and their remains widely scattered across the sea bottom. Many of Romer and Grove's conclusions on environments of the early vertebrates have been challenged, however, by Denison (1956); and Wells' interpretation, insofar as it applies to the Ohio Shale, has been disputed by Schaeffer (1962), who believes that the fishes of that formation were marine. It seems likely that many if not most of the fishes whose remains are found in the bone beds were indigenous to the overlying marine waters. Thus their remains would normally be widely scattered, and no system of fortuitous currents is needed to distribute them far and wide across the sea floor.

On a broad shelf of the dimensions indicated, it is difficult to envision how currents would be generated or where they would be going. Tides can hardly have served as the causal mechanism, for as Shaw (1964, p. 7) points out, tides were probably negligible in shallow epeiric seas, because of frictional drag of the waters against the bottom. Currents, in any case, would hardly be expected to produce uniform ripple marks, uniformly oriented, at four localities over a distance of 100 miles. It seems more reasonable to assume that prevailing winds, blowing without obstacle across immense reaches of shallow water, produced similarly oriented wave patterns that in turn formed the ripple marks.

An aspect of the ripples that seems puzzling at first glance is their large wavelength and shallow profile. Harms (1969) gives the average height of wave ripples as consistently one-sixth of the spacing (ripple index of 6). Those in the Columbus Limestone have a ripple index of 12 to 20. If the present dimensions of the ripples are those of formation, we are left to wonder how waves in the shallow sea could make ripple marks that are in places 25 inches across and 1 inch deep.

The present surface, however, is a surface of abrasion; hence it cannot represent the original ripples. Restoration of the planed-off portions of corals and other fossils suggests that at least an inch of material was removed from the rippled surface by abrasion. If we assume that the original ripples had sharper crests than at present, which stood as much as two inches above the rounded crests seen today (fig. 5), a profile may be readily produced that has a ripple index consonant with that of observation and experiment.

Baker (1970) finds that the wavelength of oscillation ripple marks, up to some limit as yet unknown, appears to be *inversely proportional* to the orbital diameter of the waves that formed them. Thus ripples with a long wavelength, like those in the Columbus Limestone, may have been produced by waves with a relatively small translatory motion. Baker gives an empirical equation relating wavelength of ripple mark to sediment size and orbital diameter. A wavelength of two feet and an average particle size of 0.3 mm (medium-grained sand) indicates an orbital diameter of 0.69 feet; a wavelength of 1.6 feet (19.2 inches) and the same particle size indicates an orbital diameter of 1.24 feet. If these figures are of the right order of magnitude, they tell us something of the size of the waves just above the sea bottom. How deep the water was or how large the waves were at the surface are questions that cannot at present be answered.

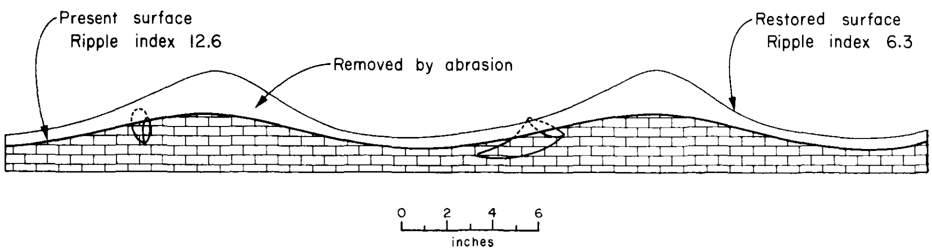

FIGURE 5. Original ripple marks may have resembled those of the restored surface (upper profile). Abrasion of the sea floor would modify the profile to that seen in the rocks today. Lower profile measured in the Klondike quarry; horizontal and vertical scales the same.

ABRASION OF THE RIPPLED SURFACES

The ripple-marked surfaces in the Columbus Limestone cleanly truncate coral skeletons, brachiopod shells, and other fossils (fig. 5). The surface that was exposed in the Klondike quarry merged laterally into a plane abraded surface of the type termed "smooth rock" by early workers in Ohio stratigraphy. These surfaces are so even as to have suggested to Stauffer (1911) that they might be shear planes, i.e., bedding-plane faults. "Fossils," he states, "are planed off as on a glaciated surface." "Smooth rock" occurs at several levels in the Columbus Limestone and equivalents, and extends for long distances. Conkin and Conkin (1969) have recognized it in the Middle Devonian limestones of Kentucky and southern Indiana.

As "smooth rock" without ripples is far more extensive than the rippled areas, it seems clear that the latter are merely local phases of widespread, cleanly swept surfaces of abrasion. Other phases may also occur. Westgate and Fischer (1933) describe places in central Ohio where the top surface of the Columbus Limestone is locally "sharply rolling," with a relief of four inches on hummocks 18 inches apart. That this irregular surface is merely another variant of "smooth rock" is attested by the fact that it "cuts squarely across" corals and large spiny shells of *Platyceras dumosum.*

It thus appears that deposition of the Columbus Limestone and its correlatives was interrupted from time to time by vigorous scouring of the shallow bottom, which was severe enough to plane off protruding fossils. It may also have removed the sharp crests of ripple marks, as previously noted; indeed, submarine abrasion might even have worn away large areas of ripple marks altogether, leaving "smooth rock" with only a few remnants of a once widely rippled sea floor.

Such a history clearly requires that, at the time of formation of the abraded surface, the substrate was sufficiently consolidated to hold protruding shells firmly. That consolidation of carbonate sediments may take place soon after deposition has been shown by Taylor and Illing (1969), who have found cemented layers in Holocene carbonates in the Persian Gulf, not only in lagoons and intertidal flats but in deeper water for more than 75 kilometers into the Gulf. Cementation is confined to sands, is near-surface, and affects only thin layers, which in places alternate with friable layers. Interestingly, they report that layers near high water have a smooth flat upper surface, due to planation by abrasion and to the work of algae during periods of exposure.

Waves, probably storm waves, are believed to have been the agents that abraded the Devonian "smooth rock." As tools they used the carbonate grains and fossil fragments of the sea floor, to which they imparted exceptionally high energy. These tools were locally abetted by quartz grains, which are not uncommon in the bone beds and other limestones that overlie much of the "smooth rock." Passing of the storm would bring the settling of detritus, the blanketing of the abraded, locally rippled surface, and its preservation in the geologic record.

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